

Ecology of a Salamander Assemblage, Including Disjunct Populations of *Eurycea lucifuga* and *E. l. longicauda*, in an Abandoned Virginia Mine

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ABSTRACT

An ecological study on salamanders in an abandoned mine near Riverville, Amherst County, Virginia was conducted throughout 2000. Species found in this mine included *Eurycea lucifuga*, *E. l. longicauda*, *E. guttolineata*, *Plethodon cylindraceus*, and *Pseudotriton r. ruber*. This location represented county records, as well as range extensions of approximately 60 km, for *E. lucifuga* and *E. l. longicauda*. Almost 50% (n = 31) of the salamanders found were *E. guttolineata*. Six *E. lucifuga* and four *E. l. longicauda* were also found. Most salamanders were found during two time periods: April through June and August through November. Larval *Eurycea* in a pool in the mine declined from a high of 25 to 0 over the course of the study and may have been prey of *P. r. ruber* larvae and crayfish. Long-term survival of the sparse, disjunct populations of *E. lucifuga* and *E. l. longicauda* in this mine remains to be determined.

Key words: cave ecology, disjunct population, *Eurycea longicauda*, *Eurycea lucifuga*, salamander.

INTRODUCTION

We found three species of salamanders in the genus *Eurycea* in an abandoned mine near Riverville, Amherst County, Virginia during field trips by the Liberty University ecology class in 1999. The species included the Cave Salamander (*Eurycea lucifuga*), Long-tailed Salamander (*E. l. longicauda*), and Three-lined Salamander (*E. guttolineata*). These findings represented new county records, as well as range extensions of approximately 60 km, for *E. lucifuga* and

E. l. longicauda. The new location is in the Piedmont physiographic region, whereas all other Virginia locations for these two species are from the Ridge and Valley and Blue Ridge Mountain physiographic regions (Mitchell & Reay, 1999). The Piedmont locality extends the distribution for Long-tailed Salamanders into an area typically occupied by Three-lined Salamanders.

Initial findings on this abandoned mine were reported by Reichenbach et al. (2000). This report details our findings of a one-year study on the ecology of the three *Eurycea* and two other species of salamanders found in this mine.

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STUDY SITE

The mine is in the Piedmont physiographic region near Riverville, Amherst County, Virginia (37° 31' 52.7" N, 78° 53' 59.4" W). Based on conversations with long-term residents of this area, the mine was active in the mid- to late-1800s, copper or iron was extracted, and it was likely abandoned by 1920. The mine entrance faces east and is about 1 m high by 2 m wide. It opens into one 88 m main horizontal channel into the side of a hill. The main channel is about 3 m high and wide. Water often drips from the ceiling and stalactites are developing. Fissures in the rock walls are only found in the first 15 m of the main channel. There are two horizontal side channels 31 m from the entrance. One channel extends 24 m and the other channel is 5 m long. A ventilation shaft appears to have been started in the area where the side channels are located. There is a spring at the back of the mine in addition to one in the back of the longer of the two side channels. The spring in the back of the main channel was seen flowing during all trips to the mine while the side channel spring was dry in December 2000. There are three pools in the mine, one large and two small, all located beyond the twilight zone which extends 10 m into the mine. The largest pool (20 cm depth, silt substrate with five small, submerged rocks at the end of the pool) extends 15-25 m along the main channel, a smaller pool (1 m², 5 cm depth, silt substrate) is located at the back of the mine, and another small pool (5 cm depth, rocky substrate) is at the beginning of the longer of the two side channels. Water temperature and pH of the large pool were measured in March 2000, and were 13°C and 6.4, respectively. Temperature and relative humidity were recorded with a Protimeter digital hygrometer ($\pm 2\%$ accuracy) 1 m outside the entrance of the mine, 1 m inside the entrance to the mine, at the intersection of the two side channels and the main channel (31 m into the mine) and at the rear of the main channel at 88 m. Temperature and relative humidity at the four locations averaged (± 1 SD, $n = 20$) starting from the entrance 23 ± 4 , 20 ± 4 , 18 ± 3 , 18 ± 2 °C and 50 ± 18 , 58 ± 15 , 63 ± 9 , 67 ± 5 %, respectively.

Other organisms found throughout the year in the terrestrial part of the mine included wolf spiders (Arachnida, Lycosidae), pillbugs (Isopoda), centipedes (Chilopoda), and cave crickets (Insecta, Rhaphidophoridae). Crayfish (*Cambarus bartonii*) were found in the large pool and small pool in the longer side channel. Little Brown Bats (*Myotis lucifugus*), Pickerel Frogs (*Rana palustris*), Wood Frogs (*Rana sylvatica*), and Eastern Rat Snakes (*Elaphe alleghaniensis*) used the mine primarily as a hibernaculum.

METHODS

We used a rope, marked off in 1 m intervals, for measuring salamander capture locations in the mine. One rope was placed along the floor of the main channel of the mine and two other ropes were placed along the floor of the two side channels. A bridge was constructed over the large pool: multiple 4 m long boards roped to concrete blocks placed in the water. This bridge allowed us to look for larval salamanders without disturbing the sediment on the bottom of the pool.

Twenty-one trips were taken to the mine throughout 2000 with at least one trip being conducted during each month. We searched for salamanders using flashlights. Rocks were sometimes turned over but an effort was made to minimize disturbance to salamander habitat. Salamanders collected were measured for total length (TL) and snout-vent length (SVL), with an apparatus similar to that described by Wise & Buchanan (1992). Before measuring larval salamanders, each was anesthetized with 0.33g/L solution of MS-222 fish anesthesia (K. Mallory, pers. comm.). Salamanders were also uniquely marked. Initially, we toe-clipped the animals, and then on 3 May 2000, we started applying permanent marks with a fluorescent elastomer (Northwest Marine Technology, Inc., www.nmt-inc.com). Elastomer was injected in various locations on the salamander (limbs, base of limbs, base of tail) with each location corresponding to a unique number. We recorded capture location as the distance from the entrance of the mine and whether animals were found on the floor, walls or ceiling of the mine. All collected salamanders were processed in the mine within one-half hour of capture and were released at their capture location.

Observations (detected or not detected) on cave crickets (Family Rhaphidophoridae) were recorded in spring, summer, and fall. We examined four areas: the main channel in front of the pool, the area around the main channel pool, the two side channels, and the main channel from the side channels to the end of the main channel.

RESULTS

The most commonly observed species in the mine was *Eurycea guttolineata* ($n = 15$; Table 1). The number of individual *E. l. longicauda*, *E. lucifuga*, and *Pseudotriton r. ruber* seen was similar, ranging from four to six. Only one *Plethodon cylindraceus* was found (September 2000 and thereafter found on two subsequent field trips).

Table 1. Number of salamanders (n = 31) observed during 2000 in an abandoned mine in Amherst County, Virginia (recaptures not included).

Species	Number observed
<i>Eurycea lucifuga</i>	6
<i>Eurycea l. longicauda</i>	4
<i>Eurycea guttolineata</i>	15
<i>Pseudotriton r. ruber</i>	5
<i>Plethodon cylindraceus</i>	1

Most of the salamanders collected were found during two time periods, April through June and August through November (Fig. 1). All of the species followed this general pattern. Before July, 15 of 16 salamanders were found in the front area of the mine from what was designated as the 'intersection' forward (entrance to 31 m into the mine). This distribution was similar to that found for the cave crickets. After July, salamanders were more evenly distributed (12 salamanders in the front and 8 in the back), while the crickets remained in the front of the mine.

Six *E. lucifuga* were captured with one recapture. SVLs ranged from 55 to 69 mm and TLs from 115 to 159 mm. The average distance they were found into the mine was 20 ± 12 m (mean \pm 1 SD). Individuals were seen in fissures in the mine wall, as well as among the rocks on the floor of the front portion of the mine.

Four *E. l. longicauda* were captured with two recaptures. SVLs ranged from 42 to 64 mm and TLs from 110 to 156 mm. The average distance they were found into the mine (11 ± 10 m) was not significantly different from that of *E. lucifuga* ($t = 1.9$, $df = 7$, $P = 0.24$). As with *E. lucifuga*, *E. l. longicauda* were seen in fissures in the mine wall, as well as along the floor of the mine.

Fifteen *E. guttolineata* were captured with three recaptures. SVLs ranged from 45 to 78 mm and TLs from 100 to 167 mm. Average distance they occurred in the mine was 34 ± 25 m from the entrance. Individuals were found primarily on the floor of the mine and they occurred throughout the mine. Of the 15 unique individuals collected, five had the typical *E. l. longicauda* herringbone tail pattern and light venter. These five individuals were recorded as *E. guttolineata* based upon Carlin's (1977) criterion of the ratio of the length of the two longest mid-dorsal stripes divided by the SVL being greater than 0.8.

Two adult *P. r. ruber* were found multiple times within 1-2 m of each other at the intersection region of the mine. The larger one (SVL 78) was likely a female and the smaller one (SVL 64) a male (Petranks, 1998). The three other Northern Red Salamanders that were caught ranged from 37 to 55 mm SVL. These smaller individuals were observed from August to October and appeared to have recently undergone metamorphosis.

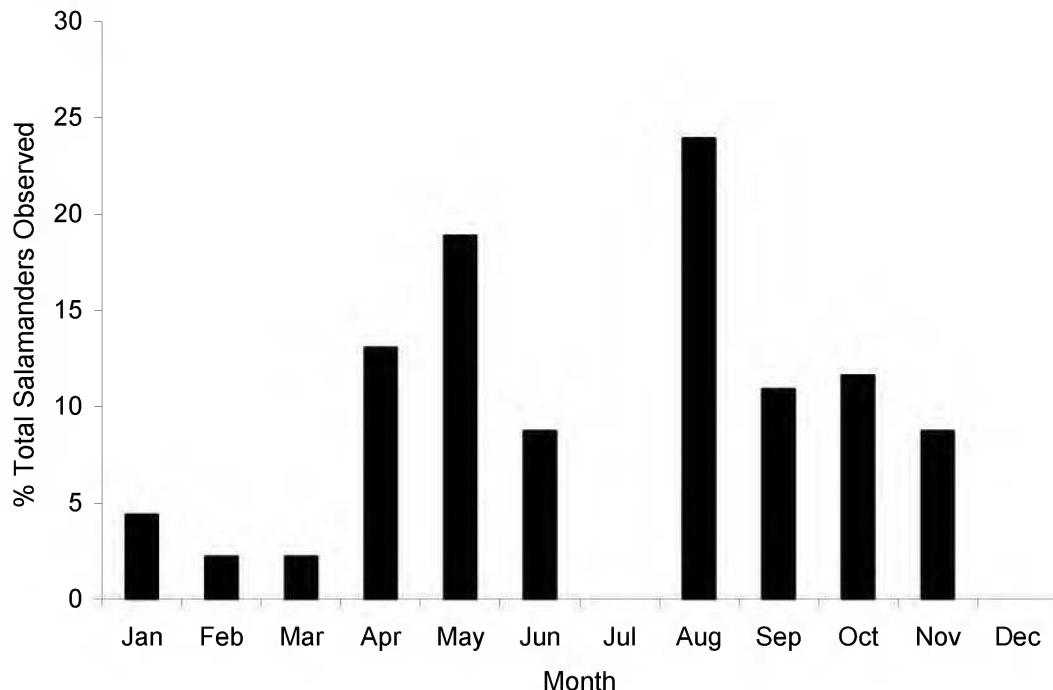


Fig. 1. Monthly variation in percent total salamanders observed in an abandoned mine in Amherst County, Virginia (n = 52).

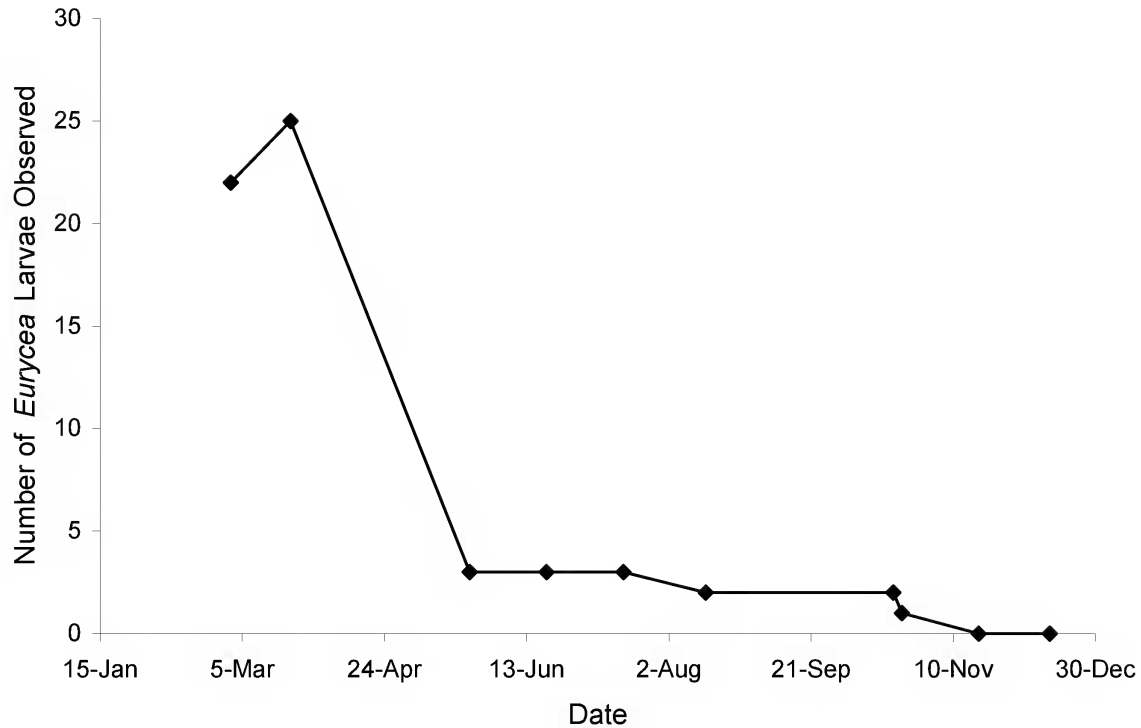


Fig. 2. Number of larval *Eurycea* found between March and December 2000 in an abandoned mine in Amherst County, Virginia.

All *P. r. ruber* were found on the floor of the mine from the intersection towards the back of the mine, at an average distance of 41 ± 15 m from the entrance. We caught seven large larvae (SVL 42–48 mm; TL 65–90 mm) in addition to the adult and recently metamorphosed Northern Red Salamanders.

Larvae of *E. lucifuga* and *E. longicauda* complex (*E. l. longicauda* and *E. guttolineata*; Petranks, 1998) were first seen on 2 February 2000. Seven *Eurycea* larvae measured on 22 March 2000 had an average TL of 21 ± 3 mm. The number of *Eurycea* larvae declined over time and none were seen during the last two trips in November and December (Fig. 2).

The entire tail or the tip of the tail was missing for three adult salamanders (two *E. guttolineata*, one *E. l. longicauda*). Two were found by the large pool in the main channel where most of the crayfish were found.

DISCUSSION

The spring peak in activity follows that found by Hutchinson (1958) and appears, at least for the Cave Salamander, to be related to salamander emergence from deep crevices occupied during winter months. Most of these salamanders were found in the front half

of the mine where they may have been feeding on cave crickets since Orthoptera are known dietary items for Cave and Long-tailed salamanders (Anderson & Martino, 1967; Hutchinson, 1958). Our second activity peak was in late summer and early fall. This peak, along with a more even distribution of salamanders in the mine with some being around the pool, may be associated with fall breeding/egg laying activity for the *Eurycea* species (Petranks, 1998). Changes in the abundance of *E. l. longicauda* have been related to migration out of a Pennsylvania cave in the spring and then back again just before winter (Mohr, 1944). We found no evidence for this type of migration. Three times during summer and fall we examined an area to a distance of 10 m from the mine entrance without finding any salamanders.

Hutchinson (1958) found a negative correlation between numbers of *E. lucifuga* and *E. l. longicauda* and suggested that this might be due to interspecific competition. Our data indicate that both species were found primarily in the front part of the mine where there were numerous fissures in the rock wall. Average capture location distances from the mine entrance for the two species were not significantly different and hence our data do not support the view that the presence

of one species has a negative effect on the other species.

While *E. l. longicauda* and *E. lucifuga* are commonly found in caves and abandoned mines, the other species seen in this mine are not associated with subterranean habitats (Petranka, 1998). *Eurycea l. longicauda* has been found in large numbers (100s) in a mine similar to the one for this study (Mohr, 1944). *Eurycea lucifuga* populations are typically smaller, ranging from 36 to 63 per cave (Hutchinson, 1958). In this study, populations of *E. lucifuga* and *E. l. longicauda* appear to be sparse without recruitment in 2000. A cohort of recently metamorphosed individuals is lacking as evidenced by the TLs for salamanders caught being within the adult size range for these species (100-200 mm; Petranka, 1998). The lack of recruitment may be due to larval mortality as evidenced by declines in the number of *Eurycea* larvae seen over time (Fig. 2). Mortality may be due to a) predation by large *P. r. ruber* larvae (65-90 mm TL) which may be 3+ years in age (*P. r. ruber* are known to prey on small amphibians; Petranka, 1998), b) predation by crayfish (≤ 12 cm rostrum to uropod length) which have been known to prey on larval salamanders (Myers, 1958), and c) starvation since common prey items for larval *Eurycea* such as snails, fly larvae, isopods, beetles, and mayfly nymphs (Rudolph, 1978) were never observed in the mine pools (larvae seen from February to October were similar in size to those measured in March). How and when *E. lucifuga* and *E. l. longicauda* colonized the mine is unknown and how long their sparse populations without recruitment can persist remains to be determined.

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